Review on Cognitive Cellular Network

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Abstract - *All over the world static allocation of spectrum scheme is commonly used which is allocated to specific technology based on various services such as mobile, broadcast or fixed and mobile satellite services. These wireless communication systems are represents 2G and 3G systems with all evolution phases towards 4G systems. The complexity of wireless networks needs a detailed design drafted with great care, especially related to energy efficiency and bandwidth. Bandwidth efficiency is very important parameter, as it is directly related to frequency spectrum, which is naturally core and scarce resource. But using this technique the spectrum allocation is fixed and day by day availability of spectrum is reduced. Many new wireless applications cannot be rolled out due to scarcity of free spectrum. Hence, new technique is introduced which is known as cognitive radio. The cognitive radio has been proposed as the future technology to fulfill the ever growing need of the radio spectrum by allocating the spectrum dynamically without creating any influence for the licensed legitimate users. The digital dividend of 700MHz band creates an opportunity for cognitive radio making broadband wireless access cost effective. Cognitive Radio offers a solution by utilizing the spectrum holes that represent the prospective opportunities for non-interfering usage of spectrum which requires three main tasks- Spectrum Sensing, Spectrum Analysis and Spectrum Allocation. Cognitive Radio Systems are expected to increase the efficiency of the overall spectrum use by availing new sharing opportunities and also to offer more flexibility to applications as an outcome of their capability to adapt their operations to external and internal factors. Spectrum sensing consists of fetching the characteristics for spectrum usage across multiple dimensions and parameters such as space, time, frequency, and code and deciding the type of signals which are occupying the spectrum. In this project, OFDM based Cognitive Radio and Spectrum sensing techniques named Energy Detection Based Spectrum Sensing with Wavelet packet transform and Cyclostationary Spectrum sensing are described and discussed upon.*

Key Words*: *Cognitive radio, dynamic spectrum, Spectrum sensing technique, OFDM,Energy detection method.

1. INTRODUCTION

The survey conducted by Federal Communications Commission (FCC) in 2002, shows that, it has been found that spectrum access is more critical problem than physical unavailability of spectrum. With 3G, 3.5G, 3.75G and 4G technology already being used and new technological progress in the field of wireless communication, Multimedia Broadcast and Multicast Services (MBMS) requirement has increased significantly and with the standardization of MBMS, it has gained major interest in the marketplace. Multimedia content needs more bandwidth, storage capacity and few applications shows tight delay constraints, so the necessity of optimizing the efficient use of spectrum is required to be achieved.

Cognitive radio is proving to be a tempting solution to spectral crowding problem by bringing the concept of the opportunistic use of frequency bands that are not heavily used by legitimate licensed users since they cannot be utilized by users other than the legitimate licensed users at the moment. OFDM (Orthogonal Frequency Division Multiplexing) is one of the most widely used techniques in present wireless communication systems which have the capacity to fulfill the needs of cognitive radios inherently or with few minor alterations. With it interoperability among the various protocols becomes easier which is one of the important requirements in Cognitive.

1.1 Cognitive Radio

CR (Cognitive Radio) is a technology especially categorized in the development of wireless communication. This system is developed and built on software defined radio. This is an emerging technology which provides a platform for supple radio systems, multi-standard, multiservice, multiband, re-configurable and re-programmable with the software for Personal Communication Services (PCS). Technique of sensing and fetching the conditional factors/details from the surrounding environment and making changes in accordance with statistical variations in run time, is used. Transmission or reception parameters are varied by the network or wireless node so that they can communicate efficiently anywhere and anytime without interfering with any type of users, licensed or unlicensed, for efficient use of the radio spectrum. It is required that Cognitive modules in the transmitter and receiver must work in a synchronization which can be achieved with the help of a feedback channel which connects them. After receiver is enabled, it conveys the information on the act of the forward link to the transmitter. Hence CR is an illustration of a feedback communication system [1].The concept was coined by DARPA(Defense Advance Research Products Agency) scientist, Dr. Joseph Mitola and the result of that idea is IEEE

802.22. This is a standard suggested for using cognitive radio for Wireless Regional Area Network (WRAN) with the help of using white spaces in the TV frequency spectrum while making certainty that harmful interference is not caused to the incumbent operation. Meaning that, digital TV and analog TV broadcasting, and low power licensed devices are not affected. IEEE P802.22.1 is a standard being developed to improve harmful interference protection for low power licensed devices operating in TV Broadcast Bands in the 700 MHz band[3]. IEEE P802.22.2 is a suggested practice for installing and deploying IEEE 802.22 System. IEEE 802.22 WG is a working group of IEEE 802 LAN/MAN standards**[3]** committee which is orchestrate to write the 802.22 standard. The two 802.22 task groups (TG1 and TG2) are writing 802.22.1 and 802.22.2 respectively

1.2 Cognitive Cycle

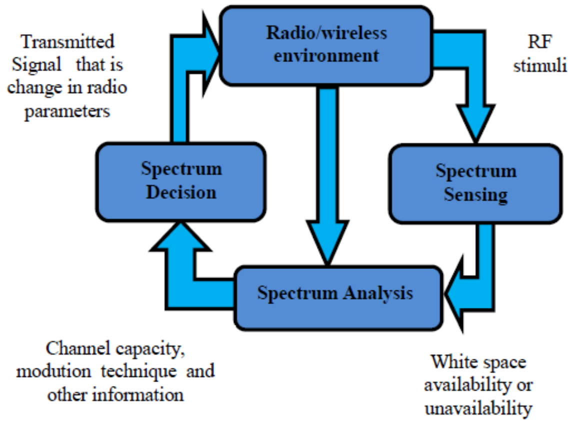

Fig-1: Cognitive cycle

A basic cognitive cycle comprises of following three basic tasks:

- Spectrum Sensing
- Spectrum Analysis
- Spectrum Decision Making

1.3 Cognitive radio's capabilities

1.3a Spectrum Sensing

Spectrum sensing is the capability of measuring, sensing and being aware of the parameters related to, availability of spectrum, the radio channel characteristics and transmit power, interference and noise, radio's operating environment, user requirements and applications, local policies, available networks (infrastructures) and nodes and other operating restrictions. It is done across Time, Frequency, Geographical Space, Phase and Code.

1.3b Spectrum Analysis

Spectrum Analysis is constructed on spectrum sensing. This is analyzing the situation of several characteristics in the external and internal radio surrounding and finding the optimal communication protocol and changing frequency or channel accordingly. This is also known as channel estimation.

1.3c Spectrum Decision Making

Spectrum Decision Making requires the reconfiguration for the channel and protocol needed for constantly adapting to mobile changing surroundings and modification of output power or even changing of transmission parameters (like modulation formats [like low to high order QAM],different channel coding schemes, variable symbol rates) and characteristics by the Cognitive radio devices. Cognitive Radio should be able to use multiple antennas for interference nulling, capacity increase or range extension.

1.4 OFDM based Cognitive Radio

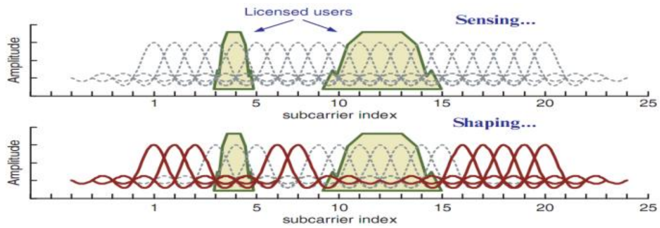

Fig-2: Spectrum sensing and shaping using OFDM [2]

OFDM signal (Orthogonal Frequency Division Multiplexing signal) can be measured as group of narrow band signals, and by enhancing the number of subcarriers, the bandwidth of each subcarrier goes narrower. It is recommended to choose the subcarrier spacing less than the coherence bandwidth of the channel, each subcarrier is going to be affected by a flat channel and hence no channel equalization is required.

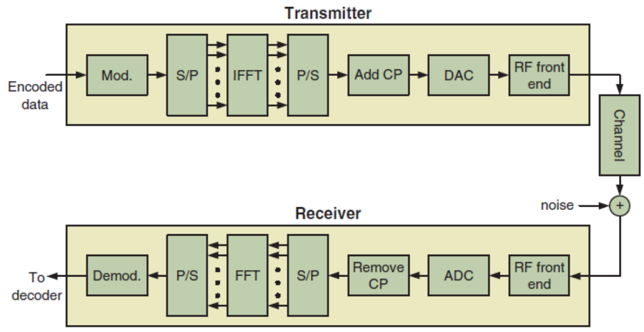

Fig-3 : Basic block diagram of OFDM transceiver [2]

Symbols duration is extended by adding a guard band to the beginning of each symbol to avoid ISI as per Cyclic Prefix (CP).Defining the delay spread (or multipath spread) of the channel as the delay between the boundaries of the received paths over the channel, the CP should be lengthier than that delay. However, for avoiding fast fading effect, OFDM symbol time is chosen as shorter than the coherence time of the channel. In the frequency domain, mobility outputs in a frequency spread of the signal. This depends on the operating frequency and the relative speed between the receiver and transmitter which is also known as Doppler spread. Doppler spread of OFDM signals outputs to Inter-Carrier Interference (ICI).ICI can be reduced by increasing the subcarrier spacing.

1.5 Flexibility offered by OFDM

The transmission parameters that can be changed based on the spectrum awareness include bandwidth, FFT size, filters, modulation, windows, transmit power, and active subcarriers used for transmission. The parameters that can be adapted depending on the characteristics of the environment in order to optimize the transmission include coding rate/type, cyclic prefix size, modulation type, pilot patterns, interleaving method, duplexing method and preambles/midambles. While employing CR, Secondary Users (SUs) should not interfere with other licensed users using the spectrum; so to guarantee an hindrance-free communication between rental users, the spectrum sensing information between multiple cognitive radio devices needs to be shared to decrease or even eliminate the probability of interference with licensed users. The processing time too plays an important role as spectrum sensing is done frequently, so the overhead of sharing such information will increase, thus reducing the spectrum efficiency of the whole system and increasing the system complexity but in OFDM systems, conversion from time domain to frequency domain is achieved inherently by using Discrete Fourier Transform (DFT). Hence, all the points in the time–frequency grid can be scanned without any extra hardware and computation because of the hardware reuse of Fast Fourier Transform (FFT) [2].

1.6 Issues associated with OFDM

While designing cognitive radio systems, mutual interference should be considered with great care. The side lobes of modulated OFDM subcarriers are large. Hence, there will [12] be power leakage from used subcarriers to nulled subcarriers causing hindrance to the licensed users. One technique is to make the *sinc* decay faster by windowing the time domain OFDM sample.

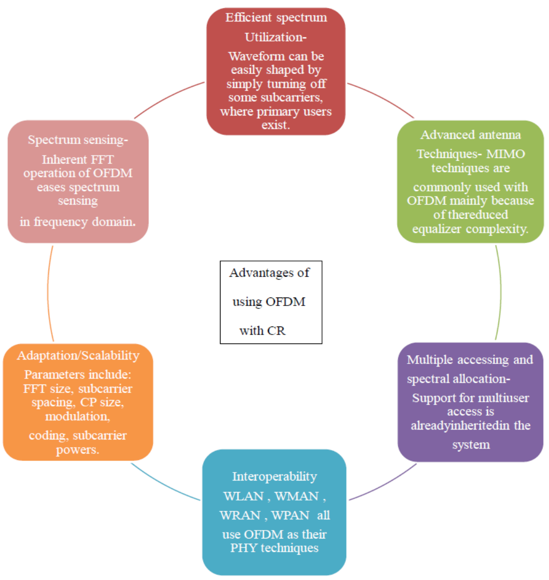

Fig-4 : Advantages of using OFDM with CR

2. Spectrum Sensing

Spectrum sensing is the capability to sense, measure and being aware of the parameters. Parameters can be generalized to be related with the availability of spectrum and transmit power, radio channel characteristics, hindrance/interference and noise, operating environment of radio, user needs and applications, local policies, available networks (infrastructures) and nodes and other operating restrictions. It is done horizontally through Frequency, Time, Code and Phase and Geographical Space.

2.1 Spectrum Sensing Methods

There are numerous techniques which are thought of investigating and identifying the presence of signal transmission. All of such methods are in early development stage.
They are:

- Energy – Detection Based
- Cyclostationary – Based
- Radio Identification Based
- Matched filtering Based

2.2 Energy Detection based Spectrum Sensing

The most common method of spectrum sensing is Energy Detection. It is commonly used as it specializes in low computational and implementation complexities. It can be said to be more generic because of its broadcasting style. The receivers do not need to know about primary user's signal. This technique uses the signal detection. It is achieved by associating the resultant of the energy detector with a threshold. This threshold is generally dependent on the noise floor. However there is a challenge involved with the energy detector based sensing. As it is the selection of the threshold for identifying primary users. Also there may be insufficient ability for differentiating hindrance/interference from primary users and noise and whenever there is poor performance under low signal-to-noise ratio values. PD (probability of detection) and PF (probability of false alarm) are the important things to be looked for energy based detection giving the information of the accessibility of the spectrum.

2.2.a Wavelet packet transform

For application of interest noise is primarily of high frequency and the signal of interest is primarily of low frequency. The wavelet transform decomposes the signal into approximation (low frequency) and details (high frequency) coefficients, the detail coefficients containing much noise. The simple method to de-noise the signal is to simply decrease the size of the detail coefficients. But it should be done prior using them to reconstruct the signal. This approach is called thresholding. The detail coefficients cannot be made zero since they contain some important features of the original signal. The two different methods which are generally applied to de-noise are hard thresholding and soft thresholding. Wavelet packet transform is a generalization of wavelet transforms that keep splitting both low pass and high pass sub-bands at all levels in the filter bank approximation and implementation. So it is suitable to finely recognize the information in both high and low frequency bands and thus is an ideal processing tool for non-stationary time-variable signal. The following figure is the wavelet packet decomposition tree.

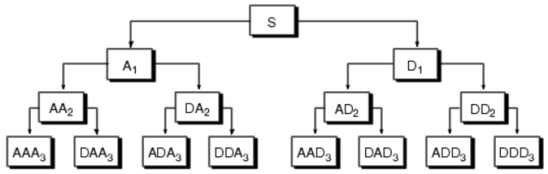

Fig-5: Wavelet packet decomposition tree

Wavelet packet analysis lets the signal S to be shown as A1 + AAD3 + DAD3 + DD2.This is an illustration of a representation that is impossible with ordinary wavelet analysis but made feasible only with Wavelet Packet Transform.

2.3 Energy detection model based on wavelet packet transform

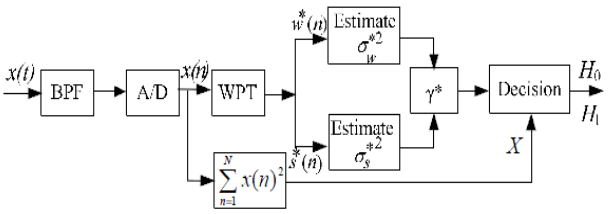

Fig-6 : Block diagram of Energy Detection Model based on WPT

The block diagram is analogous to the simplest energy based detector but most importantly a Wavelet Packet Transform (WPT) block has been introduced which estimates the current noise and signal power, which is very important for settling threshold. The analog signal x(t) after being converted into digital signal x(n) is decomposed for a certain level related to the resolution required and then is reconstructed by wavelet packet decomposition coefficients. So the noise power and reconstructed signal power is estimated.

2.4 Cyclostationary Spectrum Sensing

On modulating transmitted signal with a sinusoidal carrier, cyclic prefixes (as in OFDM), code or hopping sequences (as in CDMA); cyclostationarity is brought meaning the autocorrelation show periodic behavior. This feature is used in a Cyclostationary Feature Detector which measures a signal property that is known as Spectral Correlation Function..

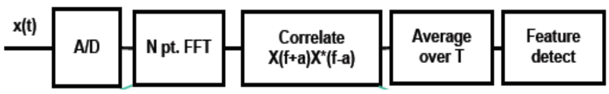

Fig-7: Cyclostationary Feature Detector

3. CONCLUSIONS

In most of earlier works, various techniques were used for sensing the input spectrum band, based on ETSI-DVB-T signal. In other paper, energy detection techniques carried out for multipath Rayleigh fading channel for known and unknown noise variance condition.

Also in some paper, Cyclostationary spectrum sensing gives better output compared to Energy detection technique at low Signal to Noise Ratios (SNRs). With Cyclostationary spectrum sensing, the primary user's modulation scheme can also be found out. However, Cyclostationary spectrum sensing is much more demanding computationally and is more complex than Energy detection spectrum sensing method.

But in our paper, we introduced the energy based detection technique simulation based on MATLAB, in that we not only improve SNR but also we improve the bit rate of given data of transmission for secondary user. And the total transmission of data can be measured in terms of energy, throughput and jitter analysis and also we shoe graphical representation of each analysis. Hence it is quite a vigorous method for spectrum sensing in Cognitive Radio when the noise is unknown.

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